Vacuum System Upgrade

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Contents

1. Issues for Vacuum System

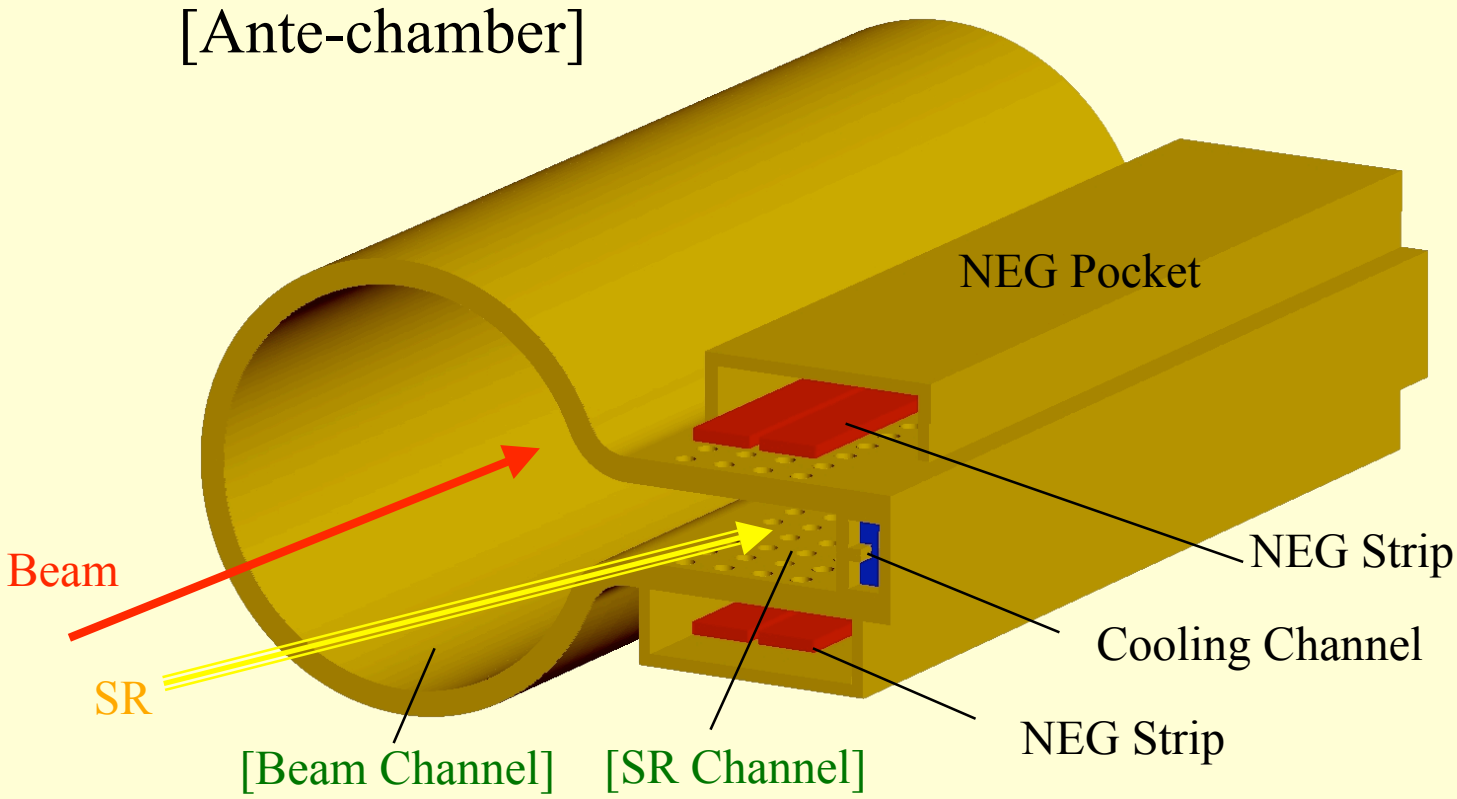
- Parameters Considered Here

	LER	HER
Energy [GeV]	3.5	8.0
Beam Current [A]	9.4	4.1
Bunch Length [mm]	3	3
Bunch Number	5018	5018
Bending Radius [m]	16.31	104.46

  - Key points in designing beam chambers and components
    - How to deal with intense SR?
    - How to reduce beam impedance?

1.1 Beam Chamber_1

- Beam chamber ➡ Ante-chamber scheme



1.1 Beam Chamber_2

- Merits of Ante-Chamber

(1) Low power density of SR

- For LER, 134 W mm^{-2} (h_a = 47 mm) [Max.475 °C]

  [9.4 A] ➡ 39 W mm^{-2} (h_a = 112 mm) [Max.156 °C]

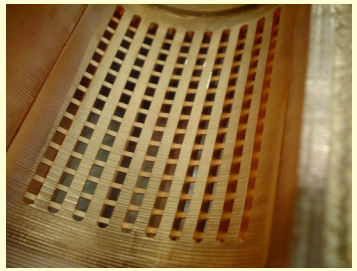
(2) Low Impedance

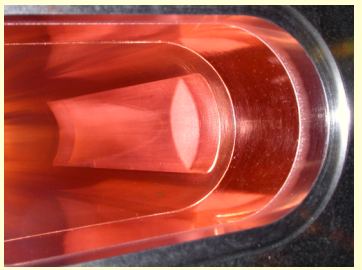
- 1 pumping port of KEKB (ϕ 94): $k = 6\times10^{7}$ V C^{-1}

  ➡ $k = 9\times10^{5}$ V C^{-1} per 1 m (~1/100)

- SR mask of KEKB (5mm height): k = ~5×10^{9} V C^{-1}

  ➡ $k = 1\times10^{5}$ V C^{-1} per 1 m (~1/10000)



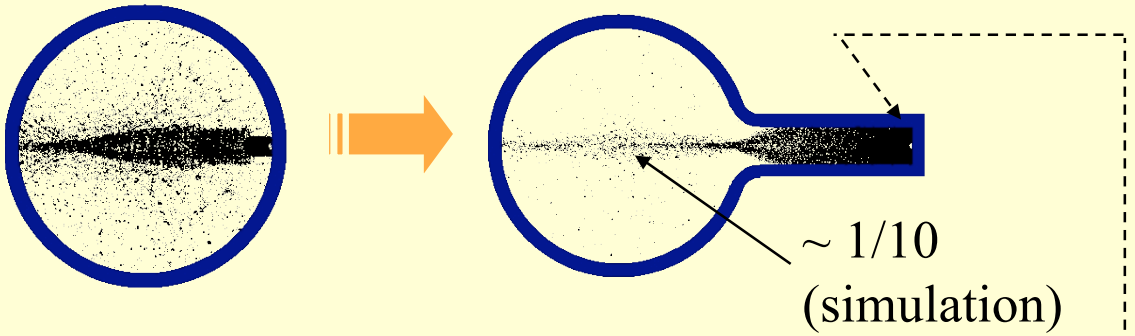


1.1 Beam Chamber_3

- Merits of Ante-Chamber (positron ring)

(3) Less photoelectrons in beam channel

- Not perfect

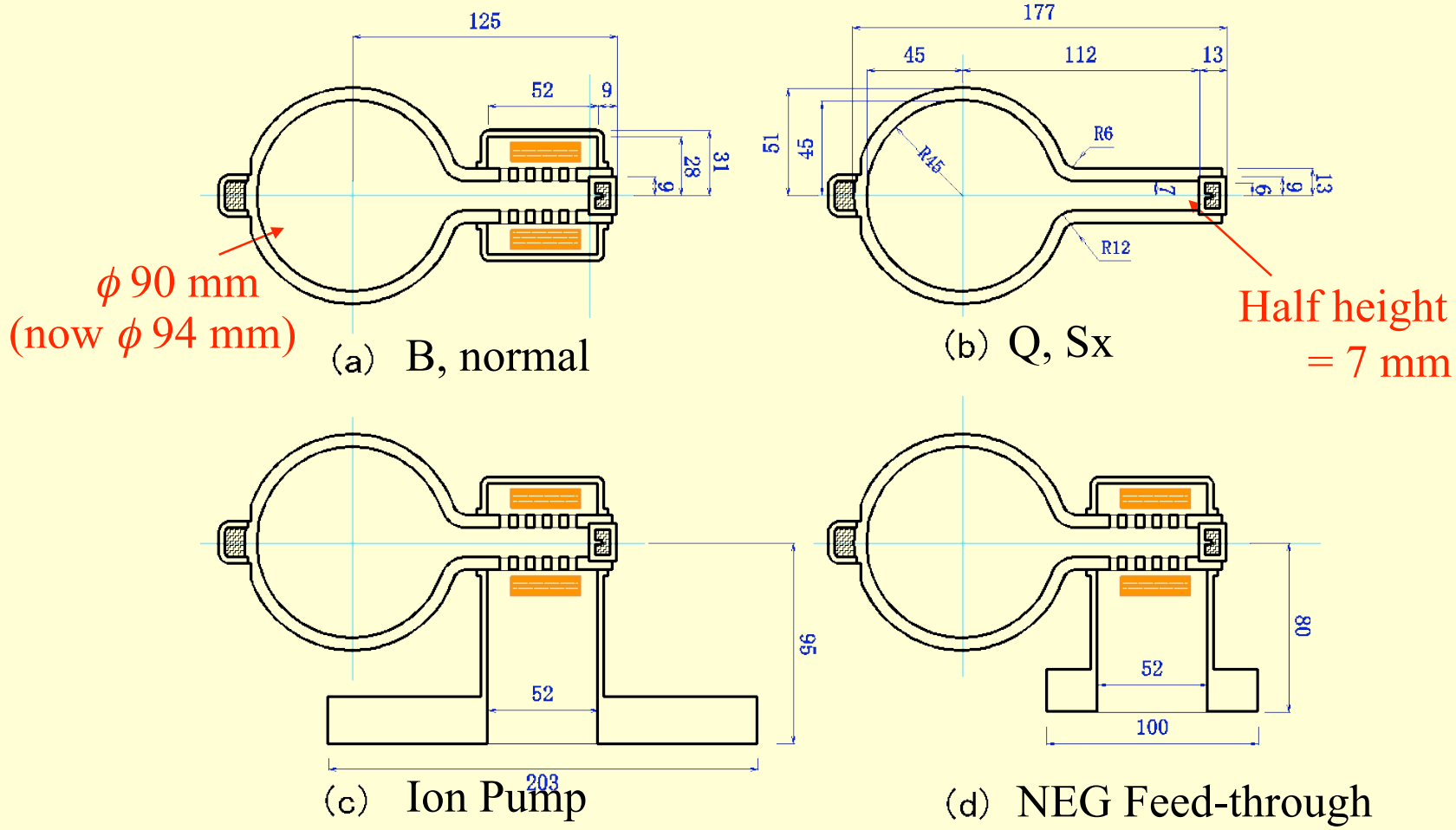


(4) Low photoelectron yield by using a rough surface on side wall (< 1/10)

- Rough surface at far side wall has little effect on beam.
- Reflection of SR is also reduced by a rough surface.

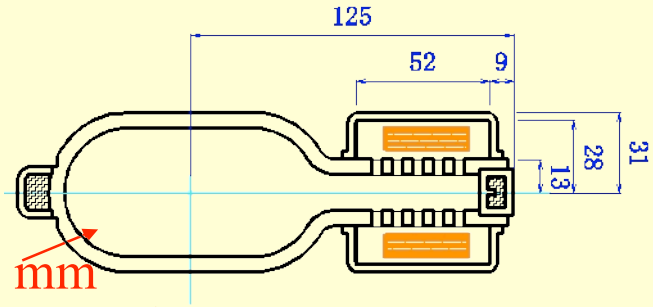
1.1 Beam Chamber_4

- Cross Sections - LER



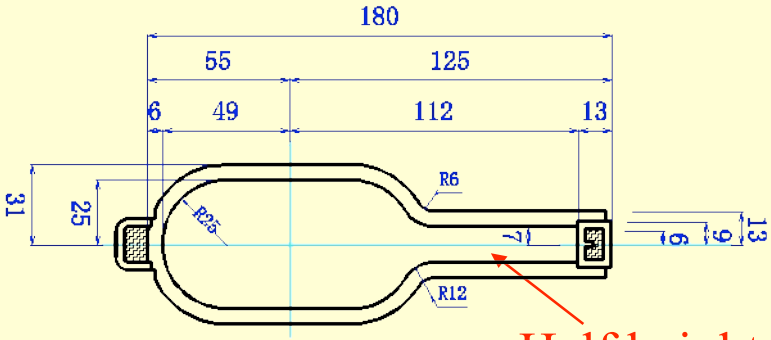
1.1 Beam Chamber_5

- Cross Sections - HER



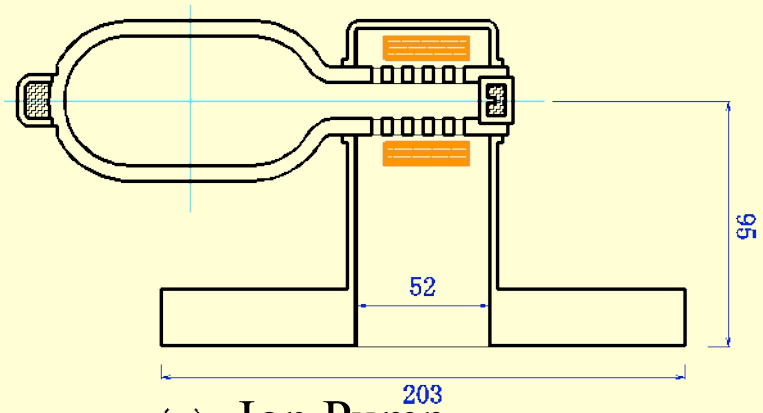
98×50 mm
(now 104×50 mm)

(a) B, normal

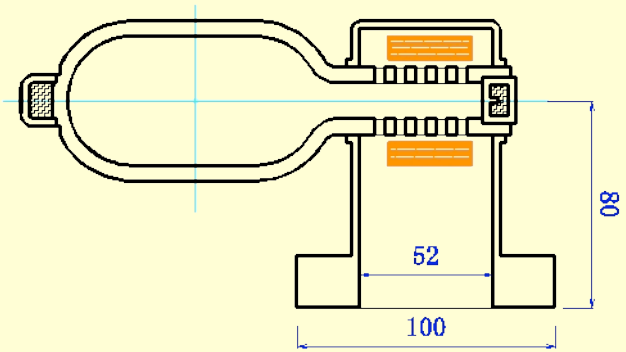


(b) Q, Sx

Half height
= 7 mm



(c) Ion Pump

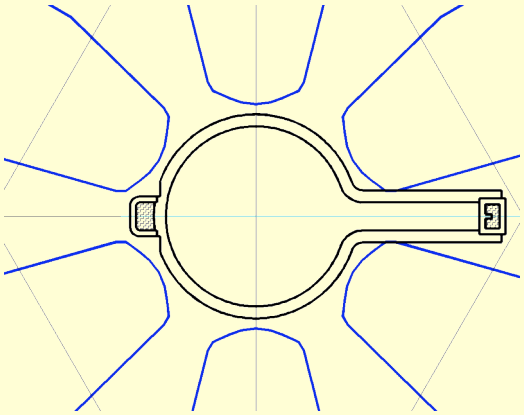


(d) NEG Feed-through

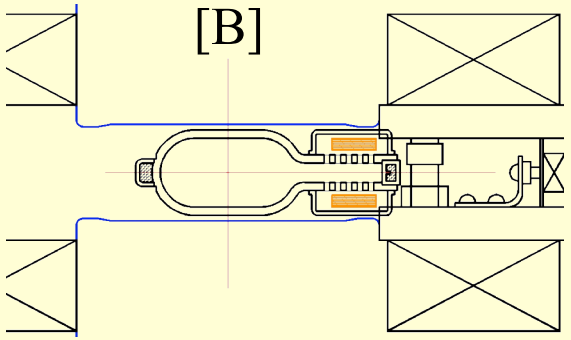
1.1 Beam Chamber_6

- Large sizes of beam chamber is better,
  - Decrease SR heat load
  - Increase conductance, capacity of pump
- But the sizes are limited by magnets
  - Q, SX:
    - Half aperture, Diameter
    - Height of SR channel
  - B:
    - Height of NEG pocket (for HER)

[SX]

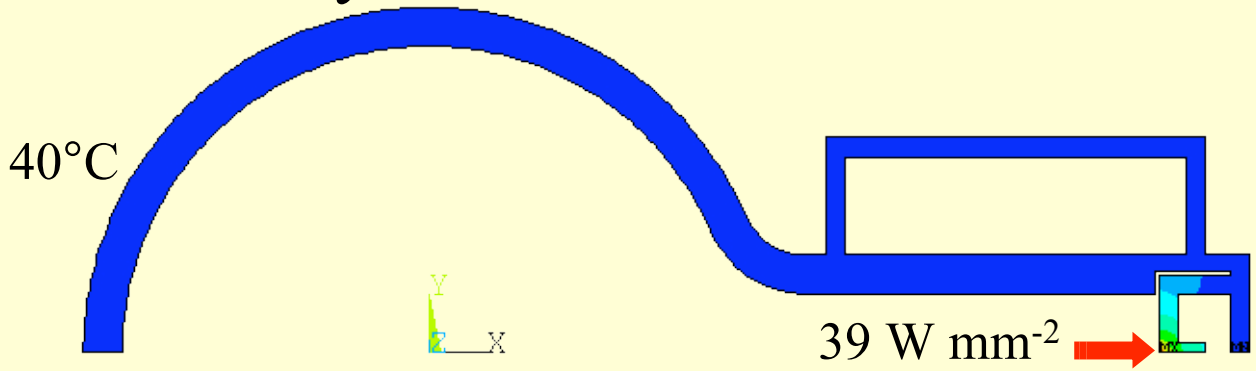


[B]



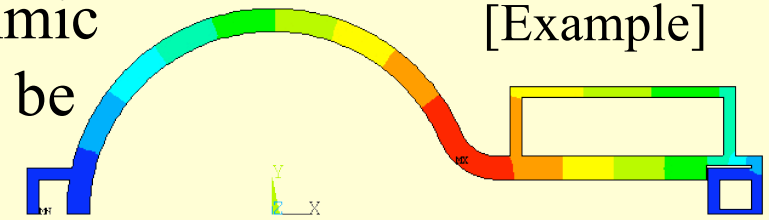
1.1 Beam Chamber_7

- Thermal analysis



- Considering HOM power or ohmic loss, extra cooling channel will be required

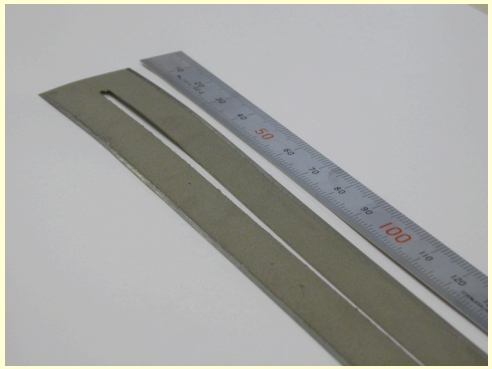
[Example]



1.2 Pumping_1

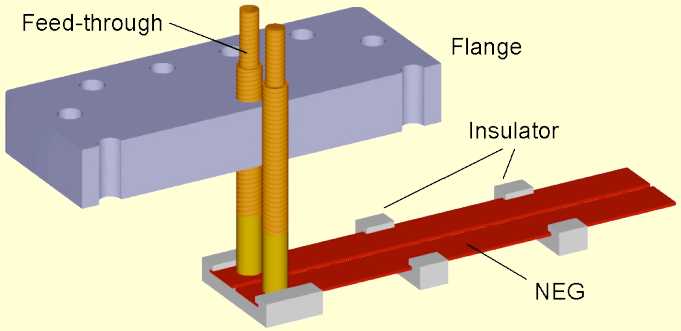
- Goal Pressure : 5×10^{-7} Pa in average
  - Beam life time ~ 10 hours (Luminosity life time ~2 hour)
  - Necessary pumping speed = 0.1 $m^3\ s^{-1}\ m^{-1}$

    (for $\eta = 1\times10^{-6}$ mol. $Photon^{-1}$)
- Pumps : Distributed Pumping Scheme
  - NEG strip (+ lumped ion pump)



[ST 707 NEG Strip]
(30 mm in width)

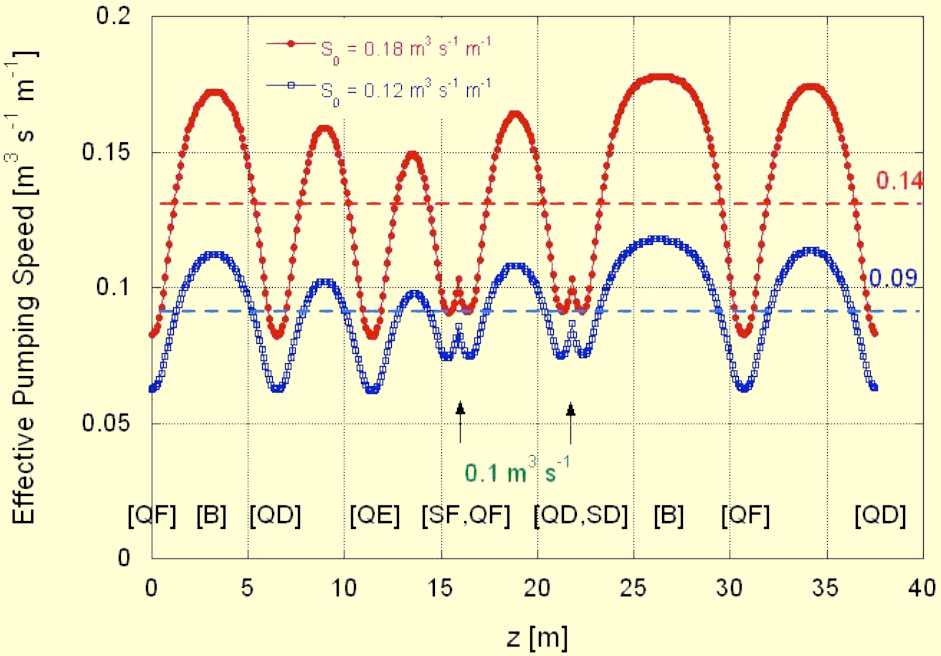
[Feed-trough for NEG activation]



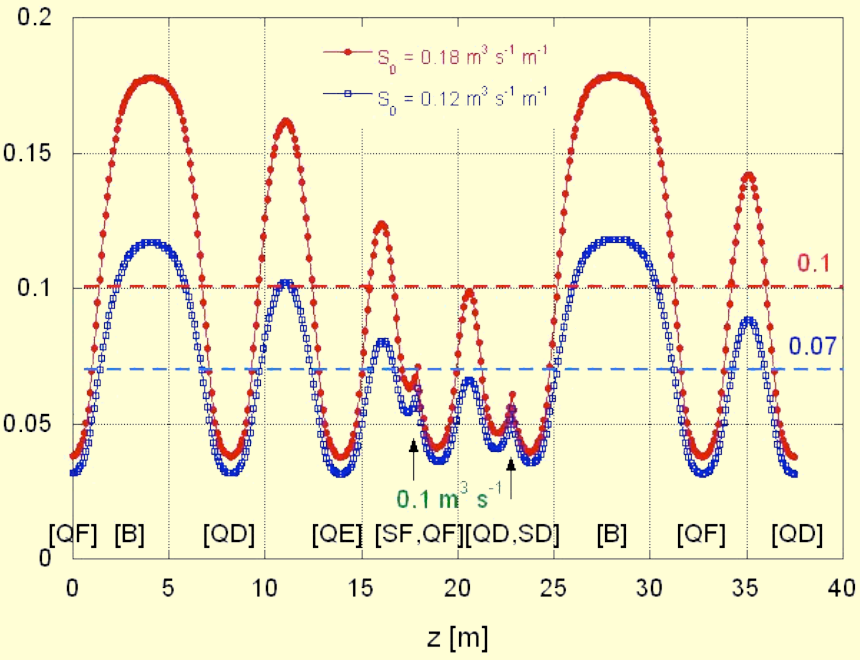
1.2 Pumping_2

- Estimation of Pumping Speed
  - NEG: 2.0 (1.25) $m^3\ s^{-1}\ m^{-2}$ (after some saturation)
  - Lumped pumps between adjacent Q and Sx (0.1 $m^3\ s^{-1}$)

LER



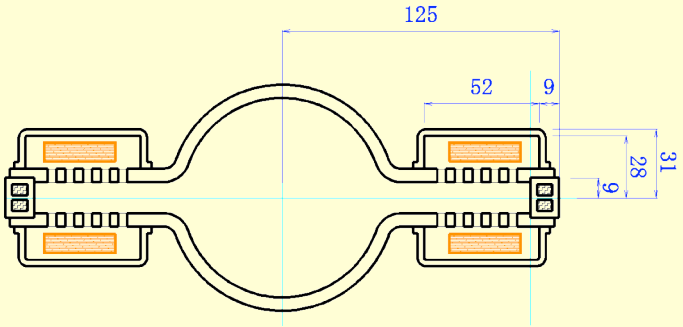
HER

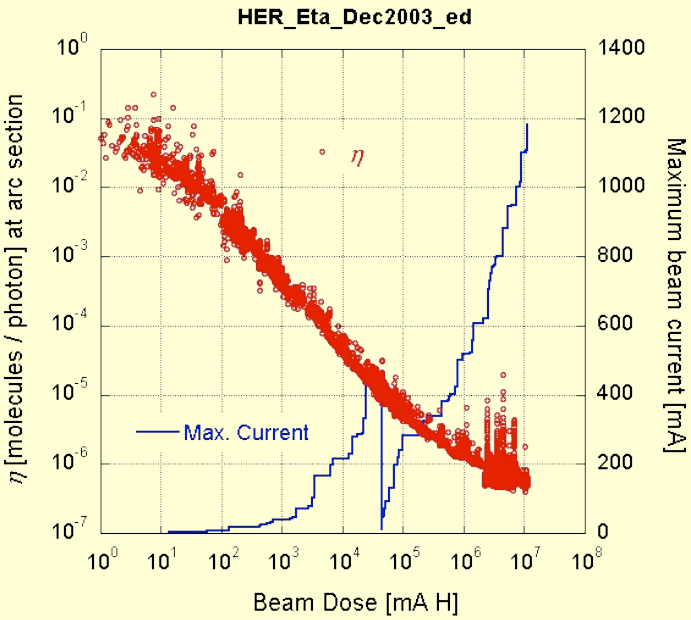


1.2 Pumping_3

- For more pumping speed
  - Double NEG strip as for chambers at Wiggler section
  - Put more lumped pumps near Q and Sx
  - Enlarge bore size of magnets and put pumps in magnets (?)
- Assumption of $\eta = 5\times10^{-7}$ molecules photon^{-1} may be reasonable nowadays
  - $\eta = 1\times10^{-6}$ may be conservative

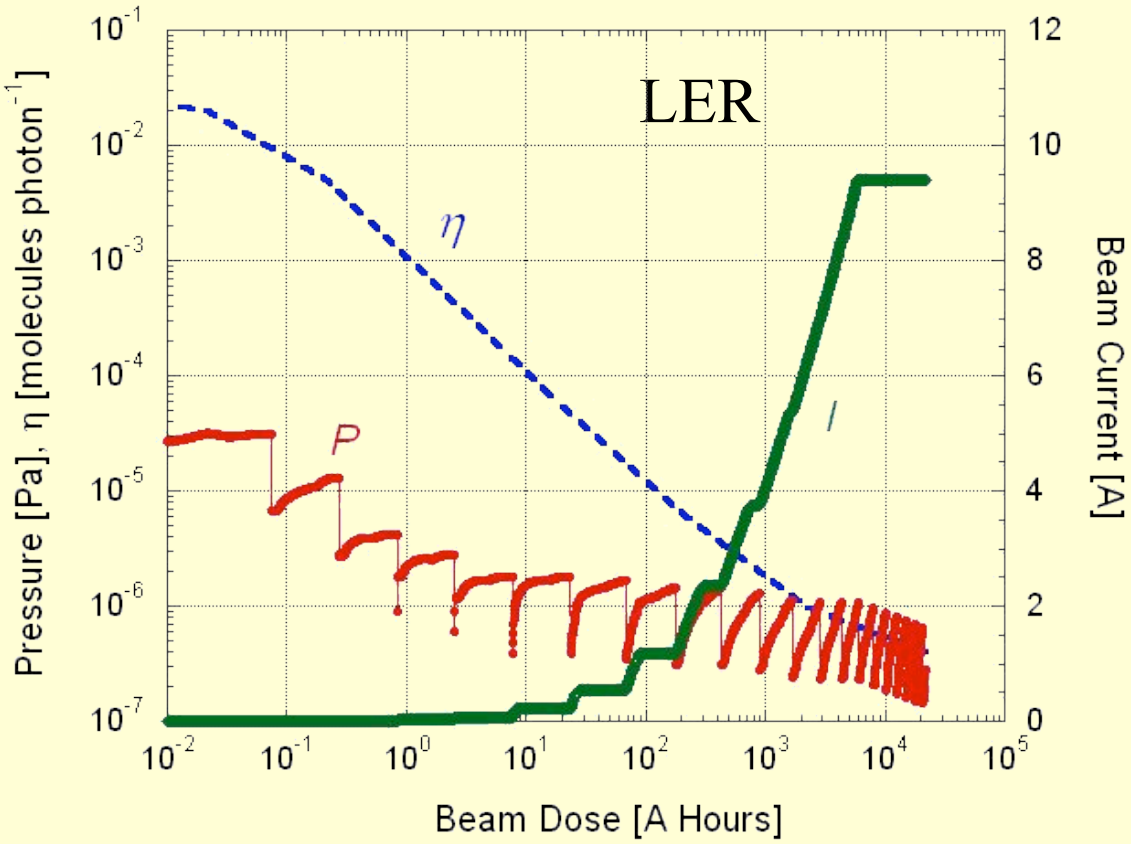
[Example at wiggler section]





1.2 Pumping_4

- Vacuum Scrubbing (simulation)



Assumption

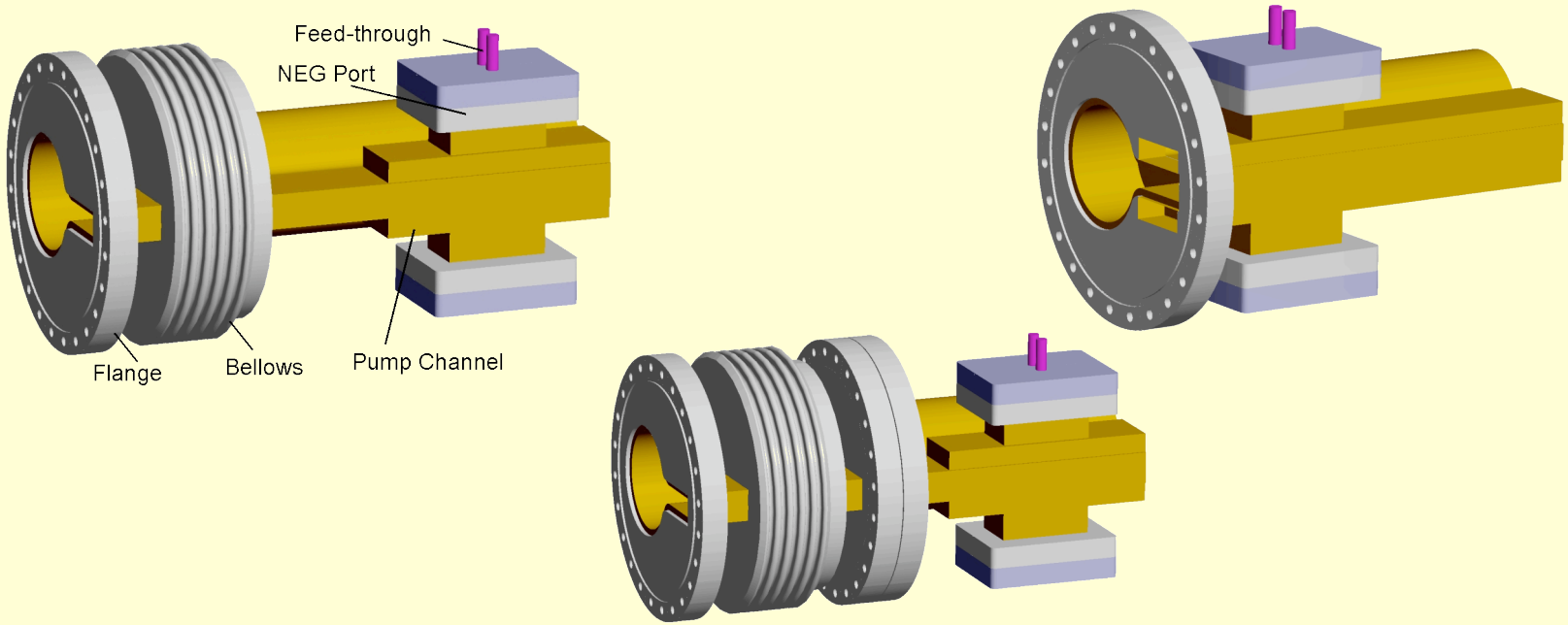
- η : Based on KEKB
- I : Increases gradually
  (18.8 mA step
  when $\tau > 5$ hours)
  (τ : Brems., CO)
- NEG : Activate when
  $S < 0.02$ m^{-3} $s^{-1}m^{-1}$

Activation >20

Need more capacity of NEG

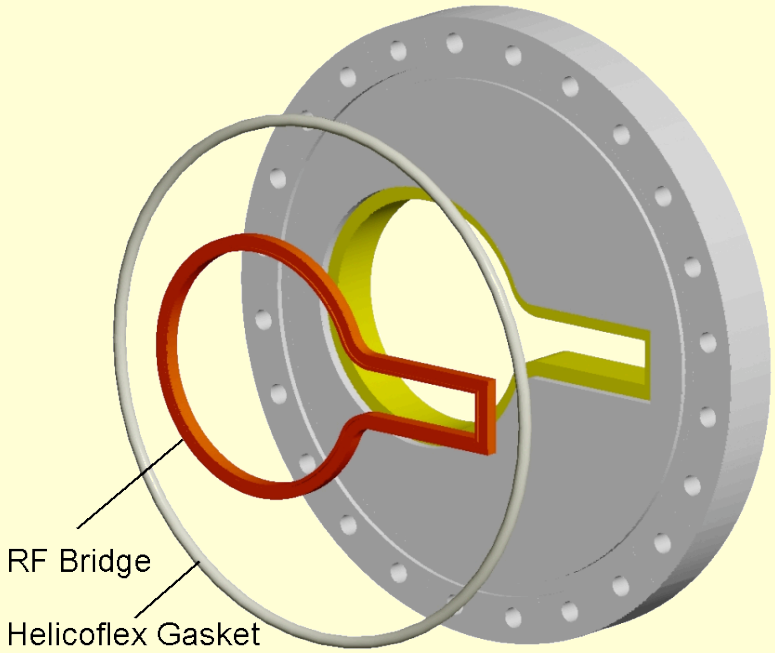
1.3 Connection_1

- Use flange + bellows to connect chambers
  - Make handling of beam chambers easy by using bellows and flanges
  - Several configurations are under consideration



1.3 Connection_2

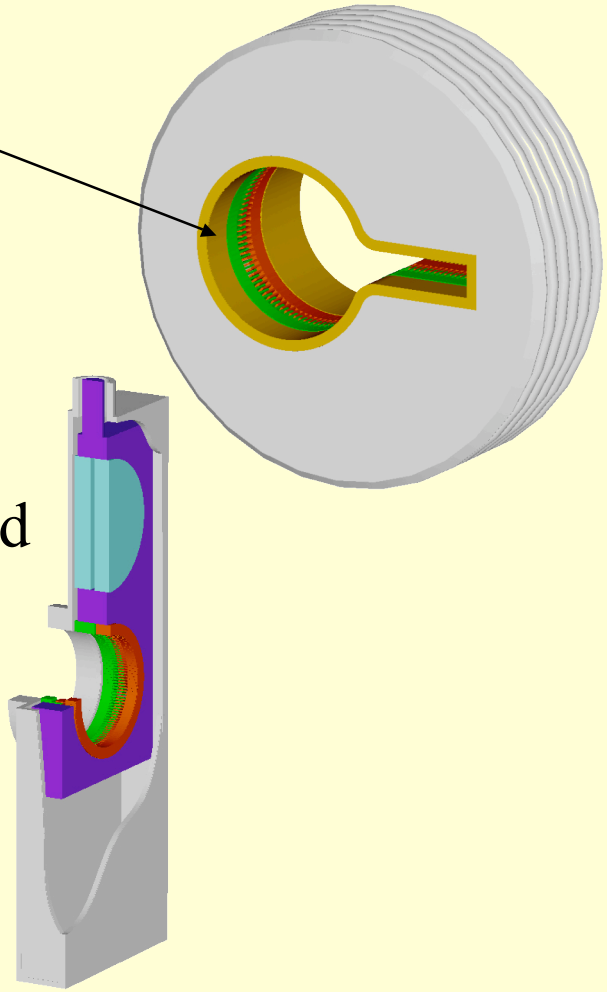
- Flange
  - Use special RF-bridge and Helico-flex
  - Or develop a special gasket that doubles as vacuum seal and RF shield



Common Problem:
How to absorb tilt between adjacent chambers

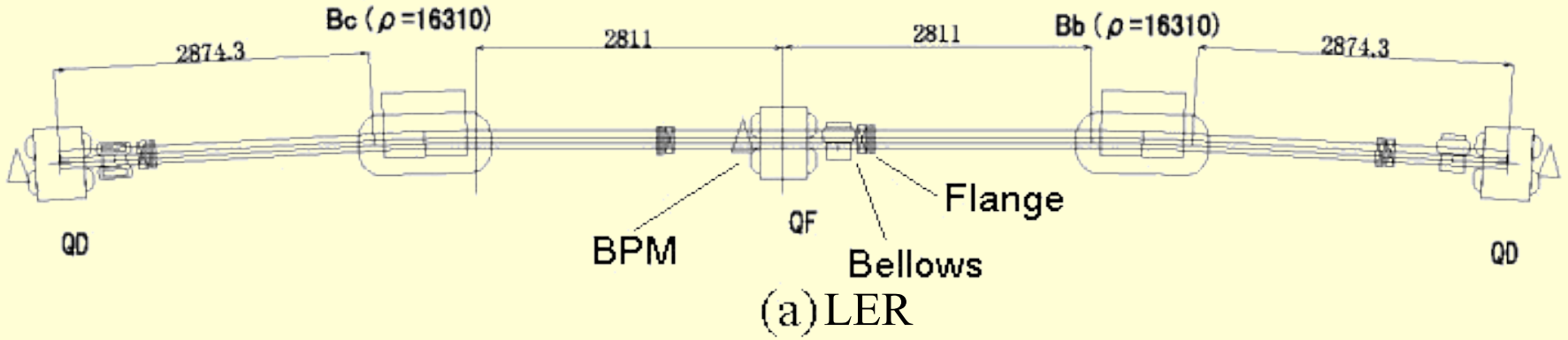
1.3 Connection_3

- Bellows
  - With new or improved RF shield to avoid HOM heating (see R&D)
  - Position feed back system for BPM is unnecessary
- Gate valves
  - Same problem with bellows
  - New or improved RF shield is required
  - Ante-chamber cross section ?
    - ➡ Tapers at both sides

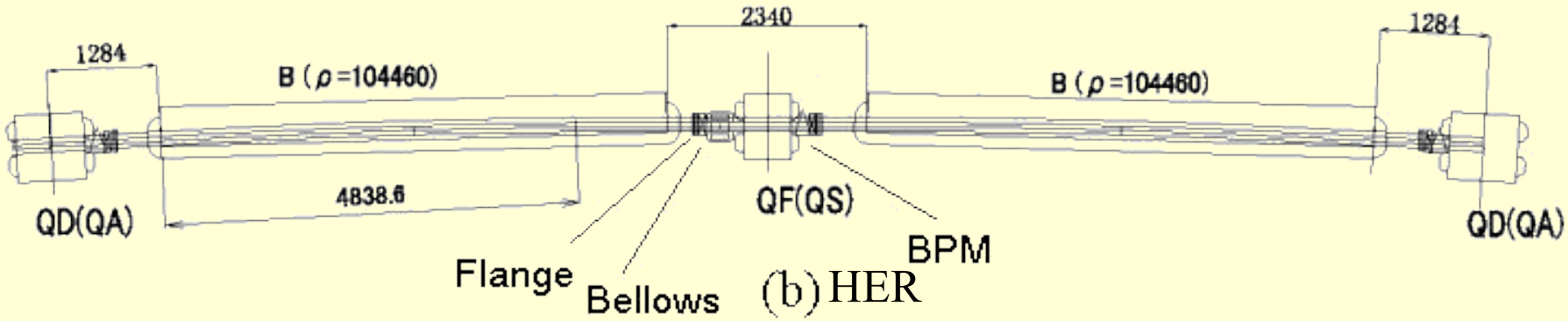


1.3 Connection_4

- General Layout (two bellows between Q magnets)



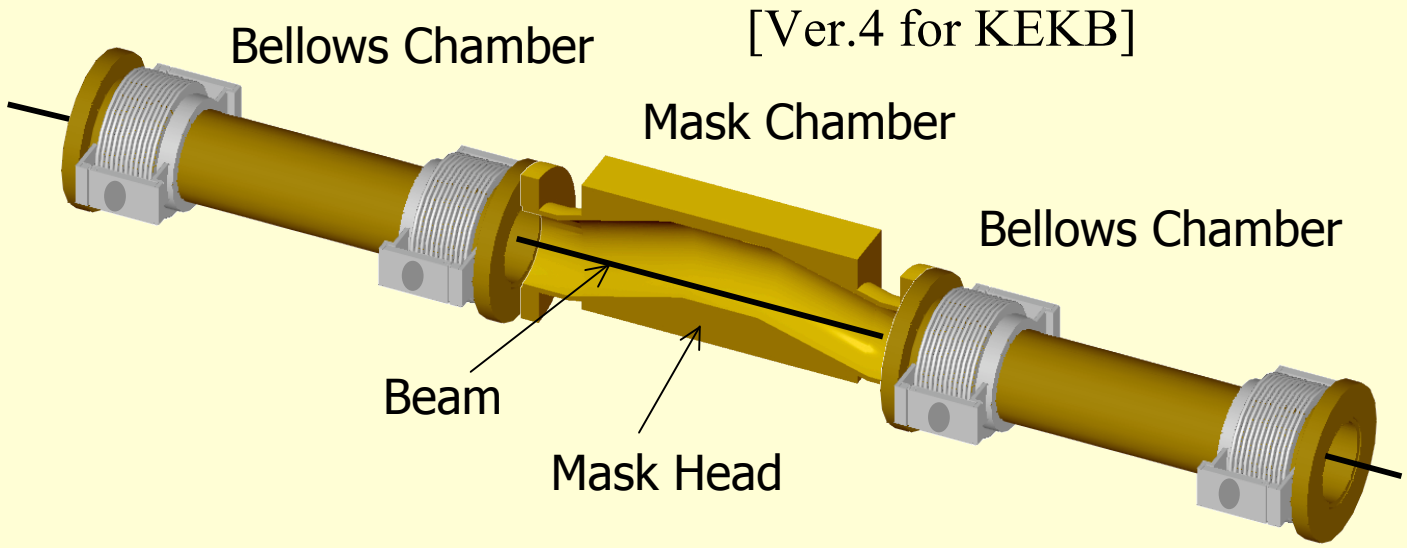
(a) LER



(b) HER

1.4 Special Components_1

- Movable Mask
  - Necessary to reduce background of detector
  - Basically the same structure with present type
  - Material of head : C or Be ?



1.4 Special Components_2

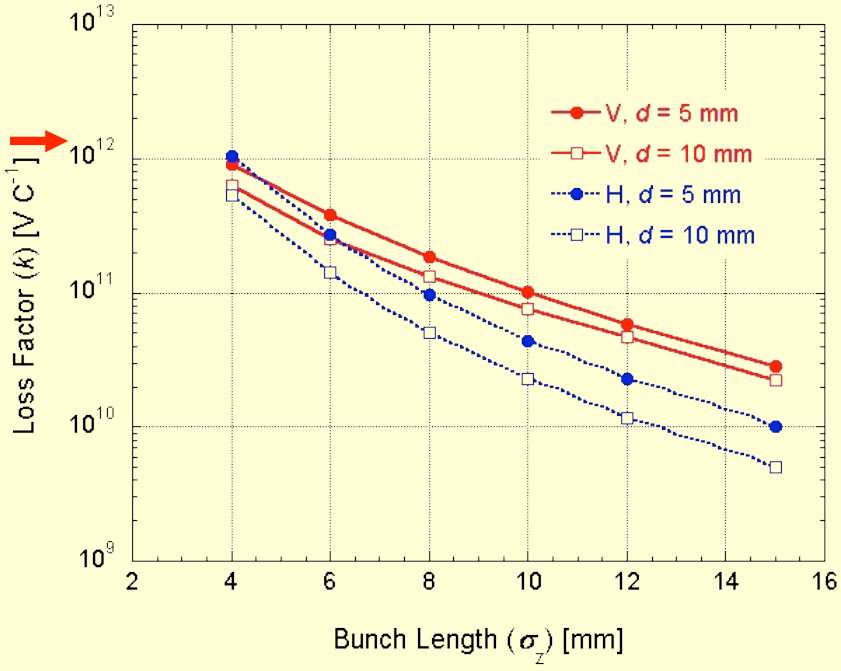
- Movable Mask
  - Problem : High Impedance
  - $k = 1$ V pC^{-1}

    @ $\sigma_z = 3$ mm

    Loss ~200 kW !!

    @5000 bunches and 9.4 A
  - Reduce number ?
  - Powerful HOM absorber ??

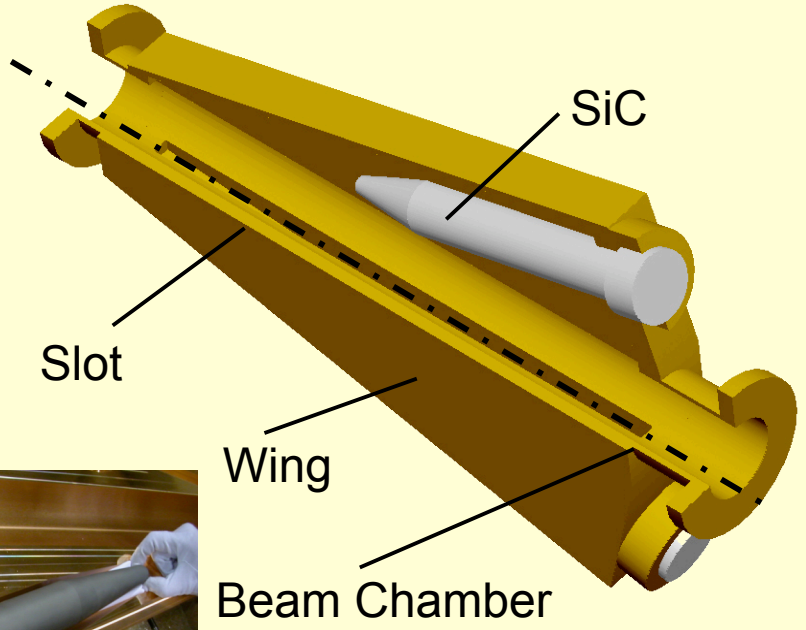
[Calculated loss factor]

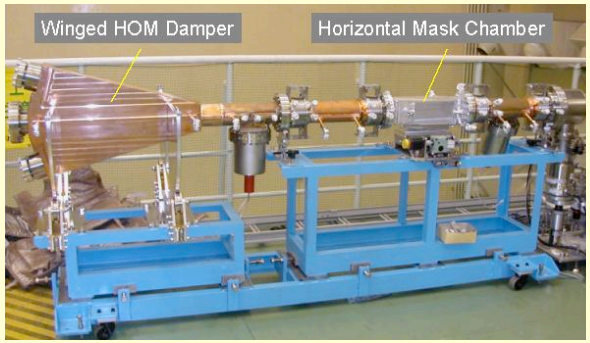


1.4 Special Components_3

- HOM absorbers for various components
  - Become more and more important components
  - More powerful absorber is required

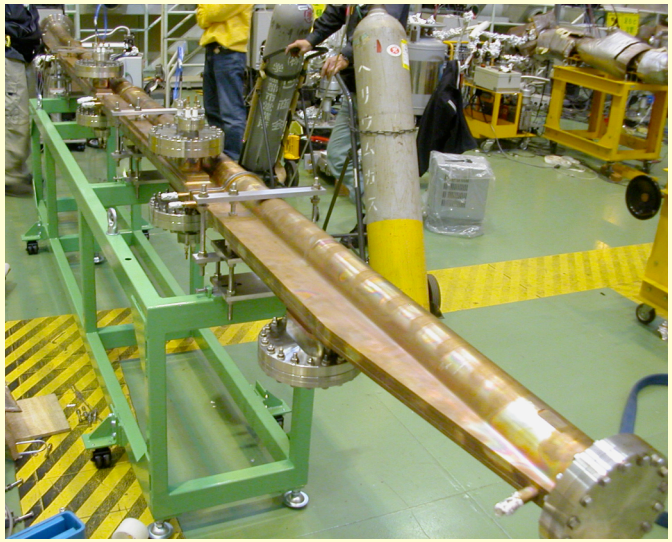
[HOM absorber for KEKB movable masks]

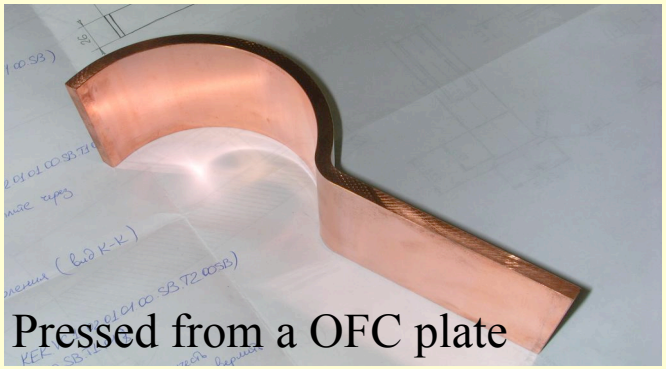


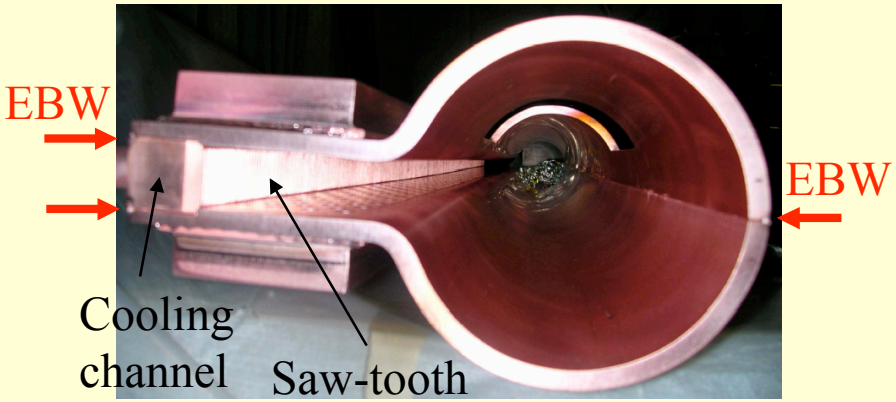


2. R&D Status_1

- Ante-Chamber_Type-1
  - Length:5.2 m
  - Manufactured in BINP
  - Material : Copper (OFC)
  - Forming : Stamp
  - Welding : EBW
  - Saw-tooth at side wall

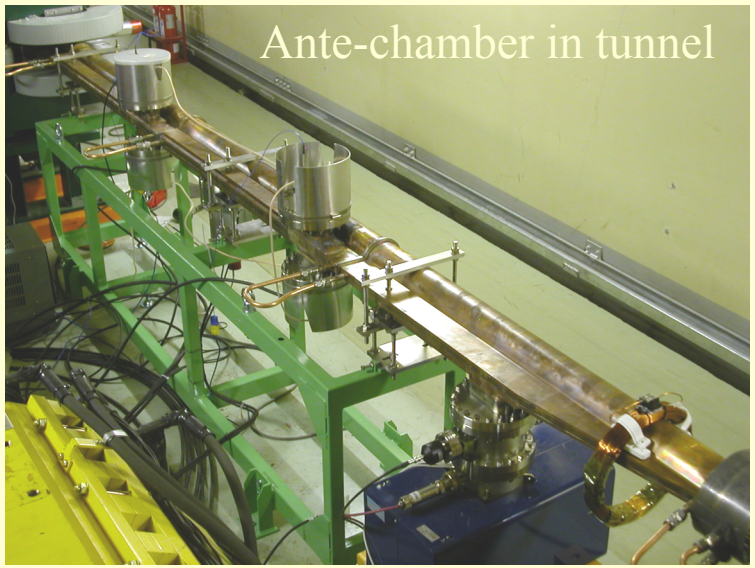


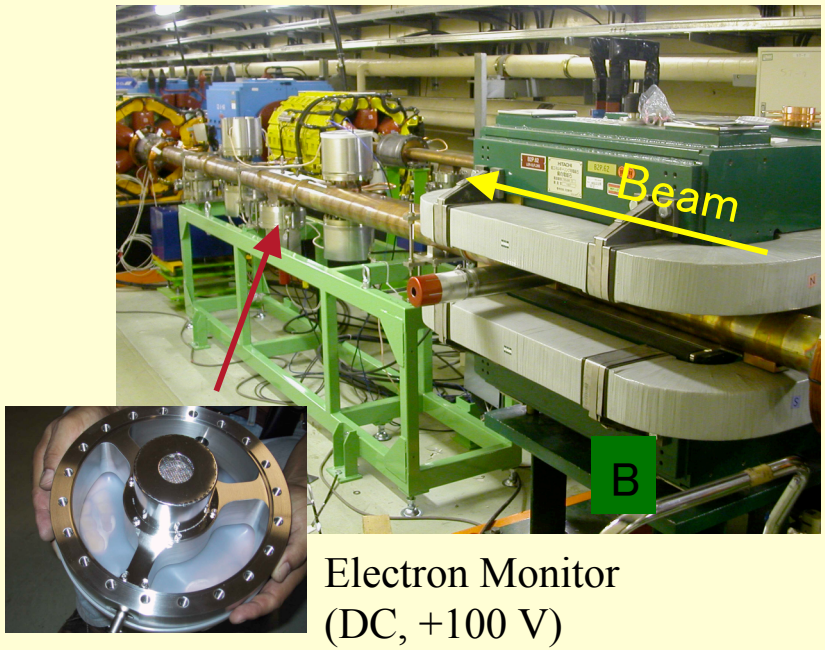




2. R&D Status_2

- Ante-Chamber_Type-1
  - Installed in LER last month
  - Electrons in beam channel and temperatures of chambers were measured



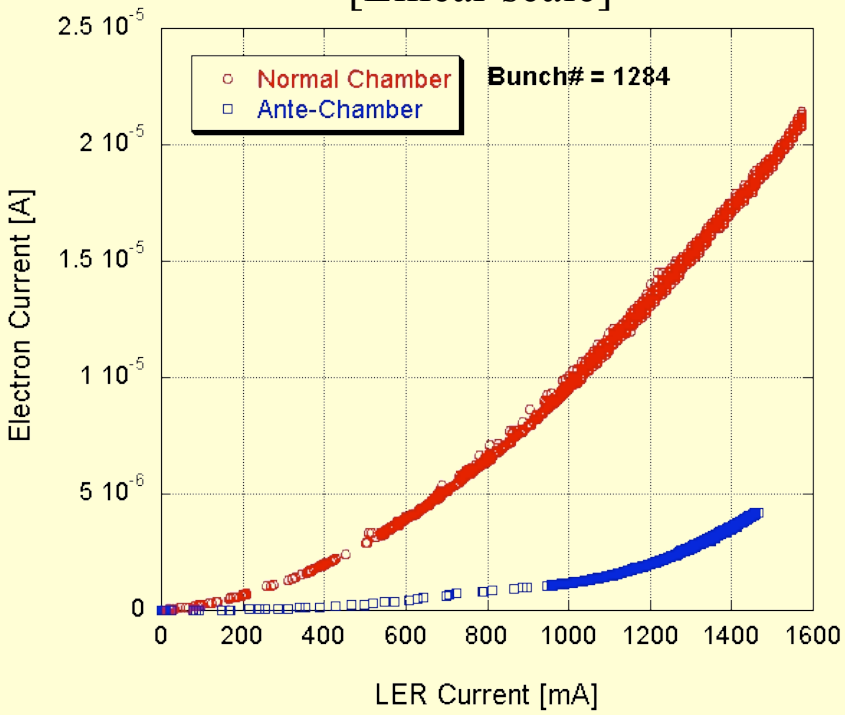


Electron Monitor
(DC, +100 V)

2. R&D Status_3

- Ante-Chamber_Type-1
  - First result of electron measurement (without solenoid)

[Linear scale]



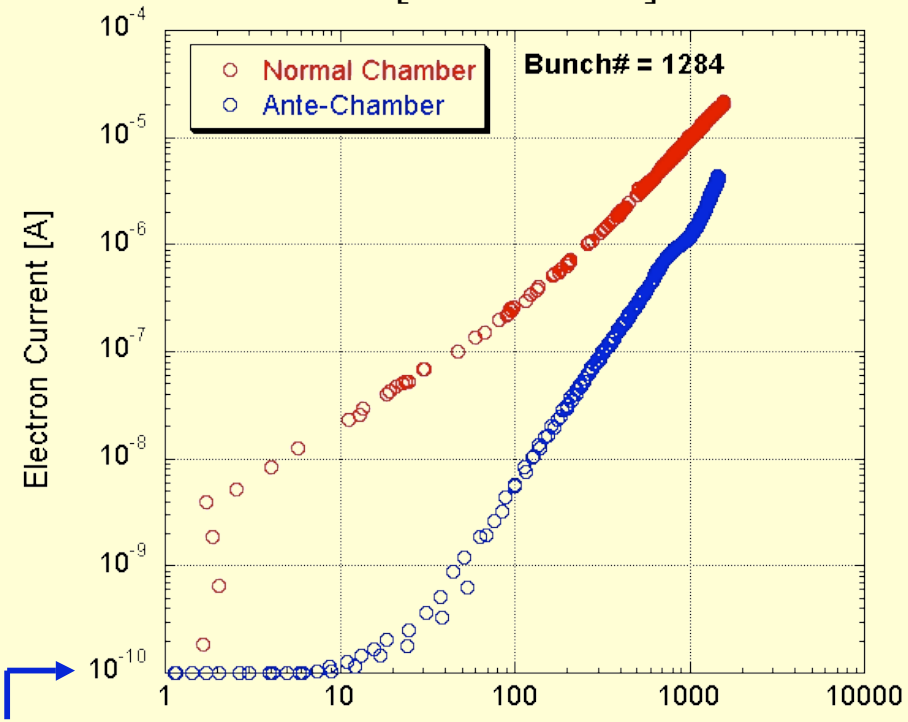
- Measured in DC mode (average)
- Bias voltage = 100 V

- Non-linear dependence on beam current
  Multi-pactoring
- Electron current for ante-chamber is smaller than that for normal chamber.
- Reduction rate is about 1/4 at 1.4 A

2. R&D Status_4

- First result

[Linear scale]

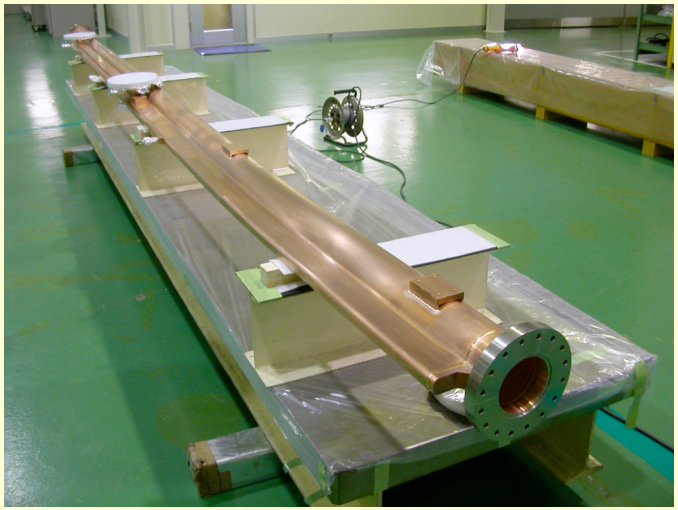


Limit of measurement

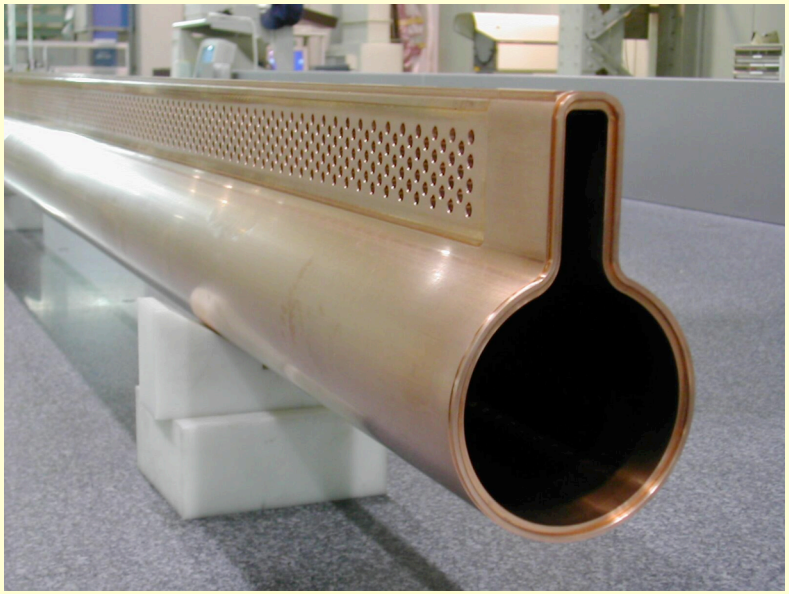
- Normal chamber:
  Photoelectrons are dominant
- Ante-Chamber:
  Multiplied second electrons are dominant
- Reduction rate is about 1/4 at 1.4 A, but 1/300 at 20 mA
- Almost in agreement with expectation:
  - Ante-chamber:~1/10
  - Saw-tooth: ~1/20
- Ante-chamber is insufficient to suppress multiplication of secondary electrons at high current.
  - Solenoid, Surface treatment ?
  - Need further investigation

2. R&D Status_5

- Ante-Chamber_Type-2
  - Under manufacturing : Almost same structure with Type-1
  - Material : Copper (OFC)
  - Forming : Drawing
  - Welding : EBW



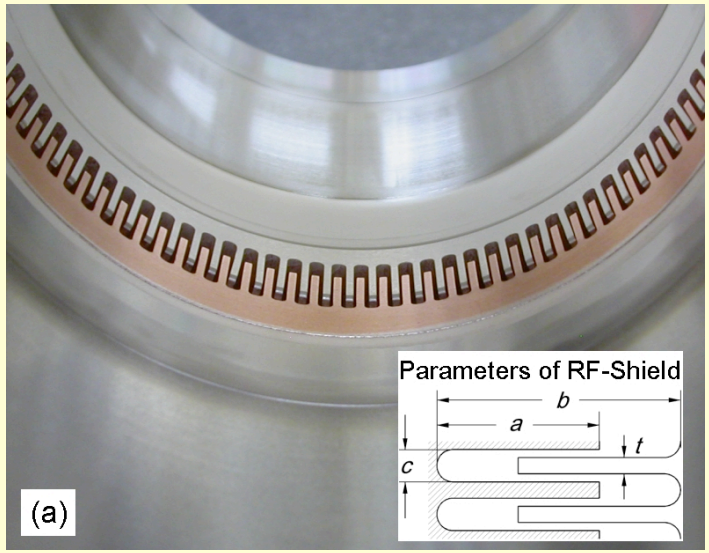
[Drawn pipe]



- Experiments and studies are under going

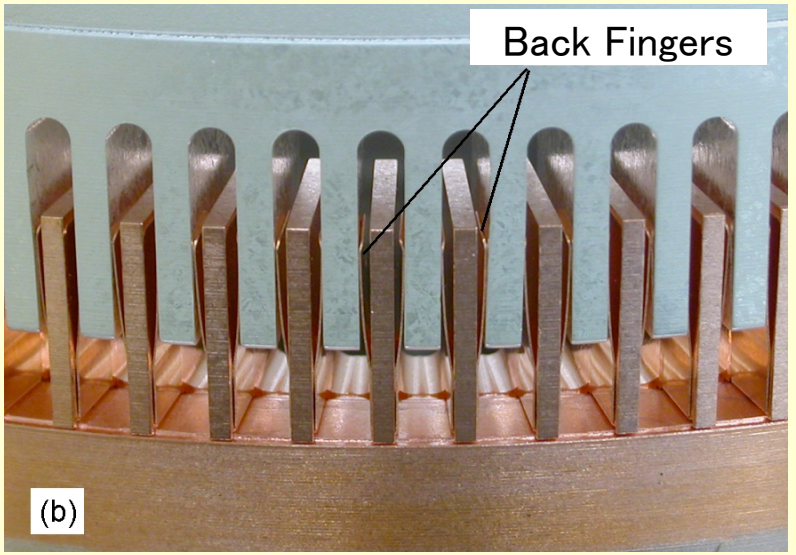
2. R&D Status_6

- Bellows (RF Shield)
  - Comb-type RF Shield
    - High thermal strength, Low impedance



Inside view

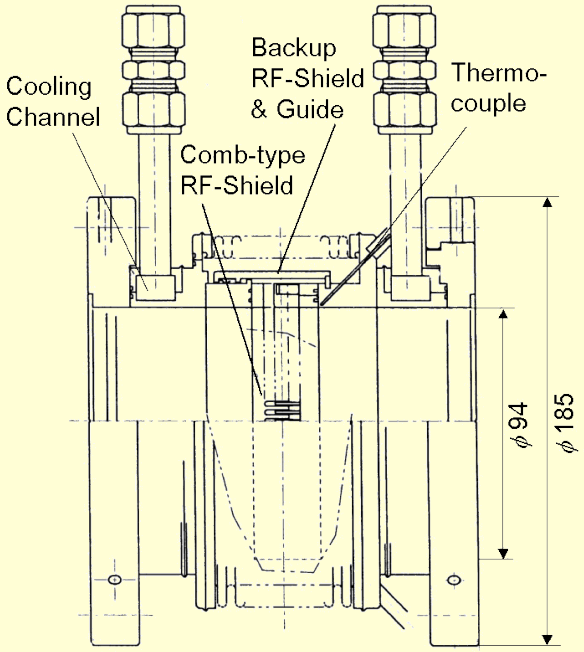
a = 10 mm, b = 15 mm, c = 2 mm



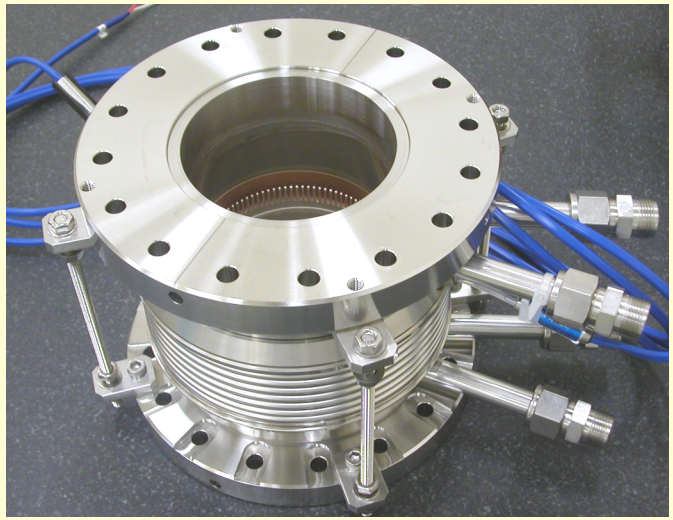
Outside view

2. R&D Status_7

- Bellows with comb-type RF Shield
  - Two trial models were installed in LER last summer at downstream side of movable masks (most severe location)
  - Temperatures of corrugation and comb were measured and compared with finger-type bellows at the same location

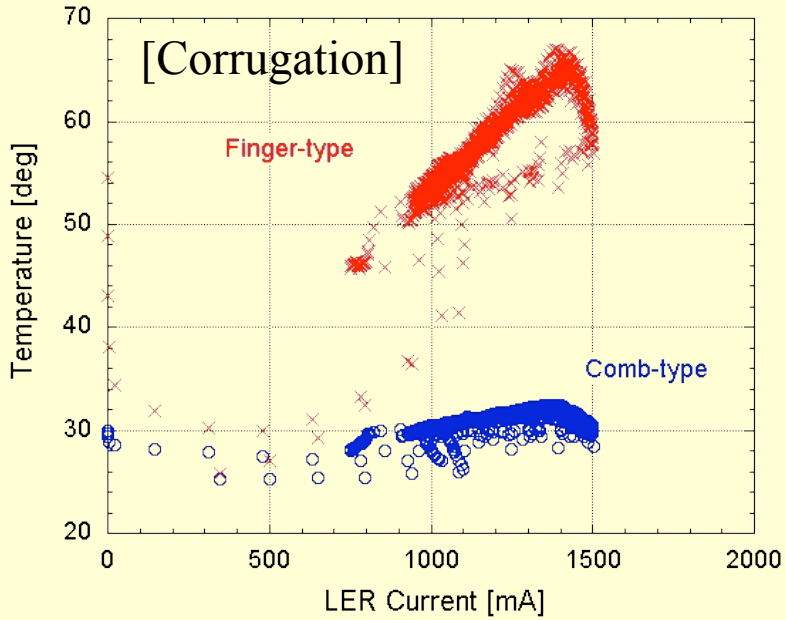


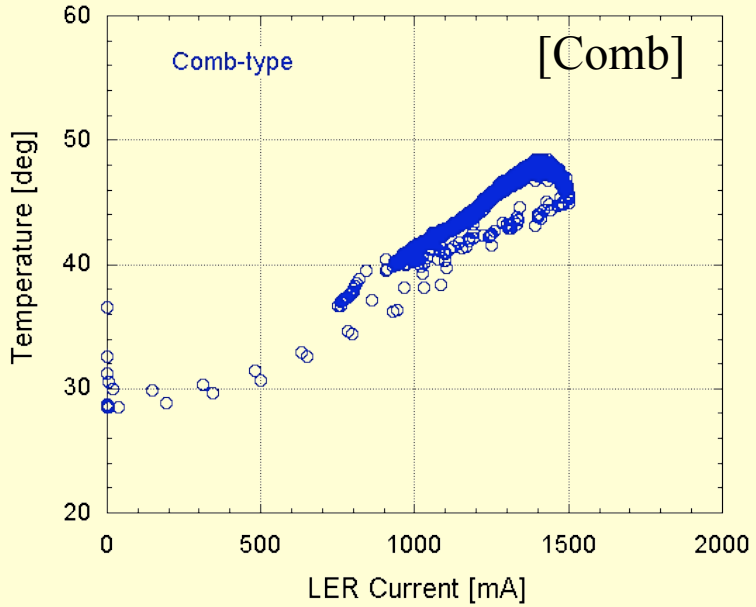
[Trial model]



2. R&D Status_8

- Results of beam test
  - Temperature at corrugation reduced to ~1/6
  - Temperature of comb is about 50°C at 1.5 A, that of finger is estimated to be ~130°C at the same condition.



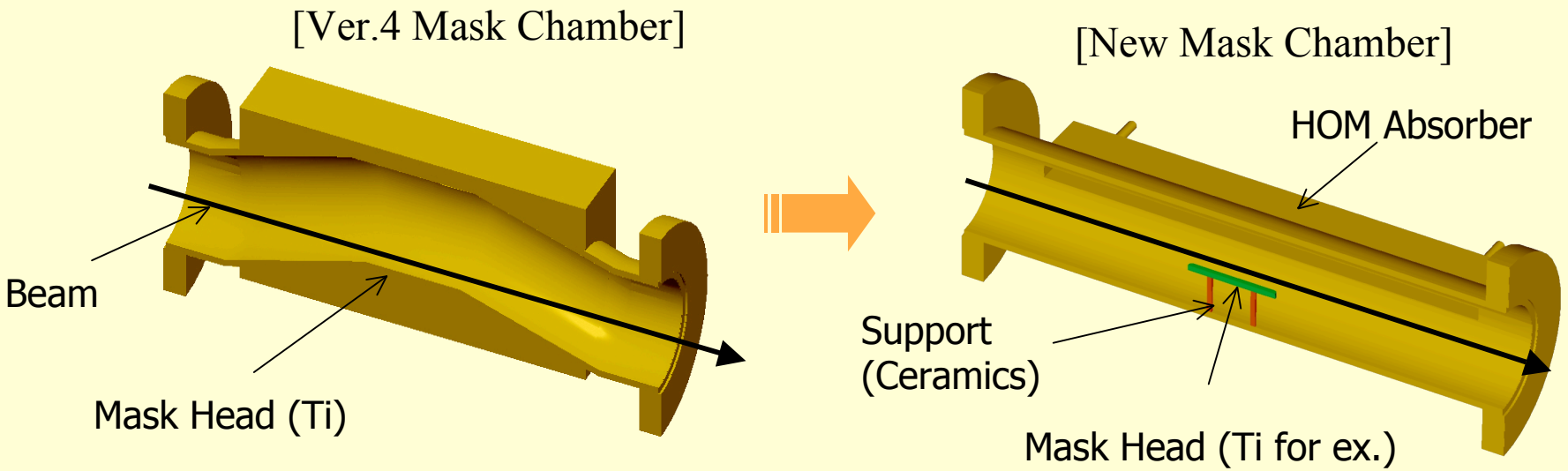


2. R&D Status_9

- Bellows with comb-type RF Shield
  - Working very well up to 1.5 A
- Problems
  - Small longitudinal movement (+3/- 4 mm at present)
    - ➡ Control of chamber temperature is required
  - Rather complex structure
- Future plan
  - Application to more small diameter chamber (~48 mm), to a race-track cross section (104×50 mm) and to gate valves
  - Simplify the structure and expand stroke

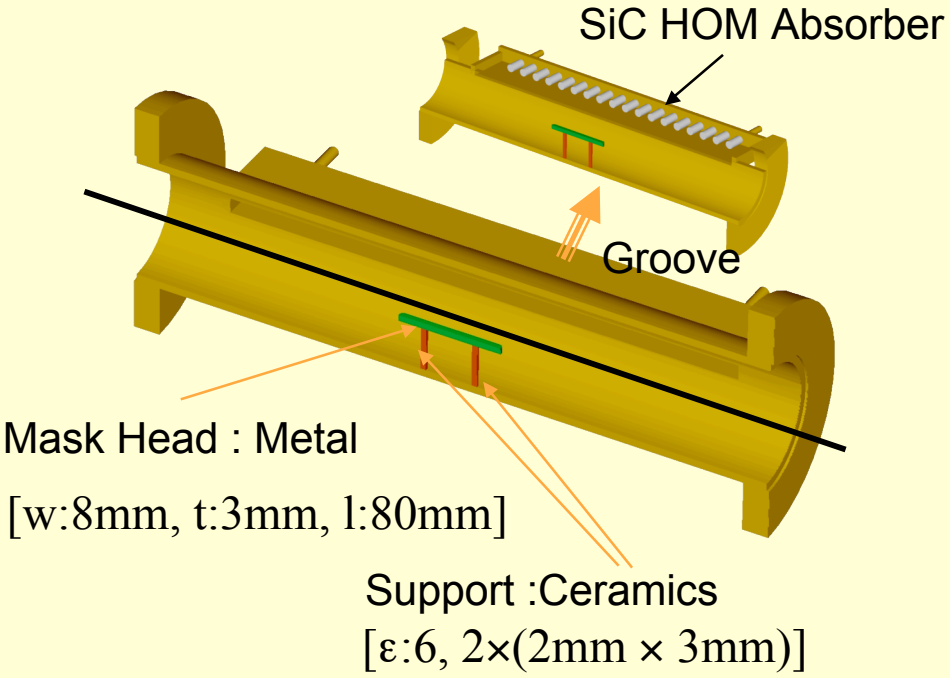
2. R&D Status_10

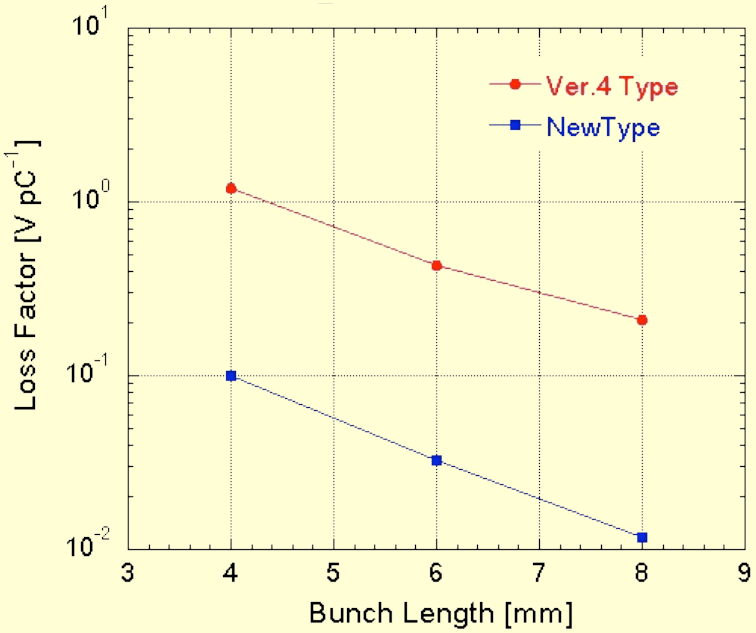
- Movable Mask
  - A big HOM source (200 kW / mask)
  - There is a limitation on the present way of thinking (make slopes gentle, for example)
- An idea for mask with lower impedance
  - Slender mask head supported by ceramics rods

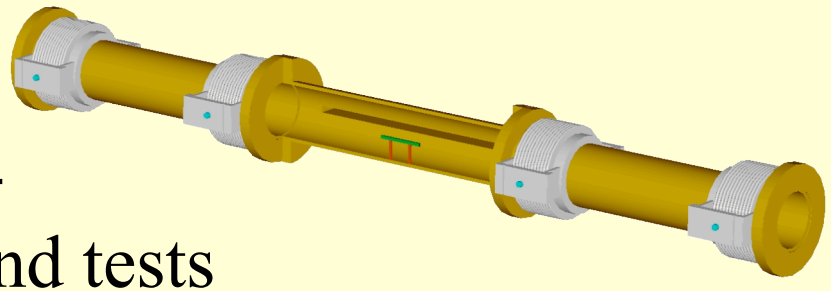


2. R&D Status_11

- Small loss factor







- Same configuration to Ver.4
- Need further investigation and tests

3. Summary

- Basic design of vacuum system is taking shape
  - The design is based on that of KEKB and introducing new ideas at the same time
  - Antechamber scheme is suitable for beam duct
  - Pumps are NEG strips and ion pumps
  - Bellows and flanges are used to connect ducts
  - R&Ds for ante-chamber, RF-shield, flange and movable masks are undergoing
- Remained issues
  - How to suppress electron multipactoring
    - Solenoid (+ coating ?), How is inside of Q or Sx?
  - Design of straight sections, IR